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TERMINAL SINKING VELOCITIES FOR A SERIES OF FLAT NOSED BODIES

A High Speed Water Tunnel Study

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SUMMARY

Drag studies were made on a series of models having varying degrees of bluntness and varying length-to-diameter ratios. Using the drag coefficients obtained from the tests, terminal sinking velocities in sea water were calculated for various volumes and densities. It was found that the terminal sinking velocity of a blunt-nosed body could be increased 15 percent if the length-to-diameter ratio was increased from 7 to 14 for the same volume. The terminal sinking velocity of a fine-nosed body could be increased only 2 percent if the length-to-diameter ratio was increased from 6 to 12.

INTRODUCTION

Drag tests were made in the High Speed Water Tunnel on a series of bodies of various nose bluntness for several length-to-diameter ratios. These tests were conducted as part of a program to develop high terminal sinking velocity shapes.

Previous studies* had been made on a series of blunt nosed bodies.[1**] Because of the interest in flat nose bodies to facilitate water entry, the present series of tests was made on bodies having various nose bluntness ratios. The nose bluntness ratio is the ratio of the flat nose diameter to the maximum body diameter. The length-to-diameter ratio was varied for each nose bluntness to determine the slenderness which would produce the greatest terminal sinking velocity.

MEASUREMENTS

The 2-in. diameter models used for the tunnel drag studies consisted of 9-caliber ogive noses, cylindrical center sections and Lyons Form A[2] afterbodies with shroud ring tails.

The model noses were progressively truncated from a pointed nose to a nose with a 1.5-in. diameter flat. For each nose bluntness the length of the model was varied from approximately 12 in. to about 28 in. The complete model series covered length-to-diameter ratios of 6 to 14 for nose bluntness ratios of 0.00 to 0.75. Figure 1 shows the models for a nose bluntness range of 0.00 to 0.75 for a length-to-diameter ratio of 10, and Fig. 2 for a nose bluntness of 0.50 for a range of length-to-diameter ratios of 6.445 to 14. The velocities used for the drag tests covered a range from 5 to 80 fps.

Pitching moment readings were taken[3] along with the drag data so that corrections could be made to eliminate the errors inherent in the High Speed Water Tunnel balance resulting from the interaction of pitching moment on drag force.

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* Tests were made on several of the previously tested models to check the effect of the interaction of pitching moment on the force measurements.[3] Small discrepancies in the drag coefficient (on the order of 5 percent) have been observed. However, the previously reported trends have been substantiated.

** See bibliography on page 4.

Drag coefficients based on cross section area were calculated and plotted as a function of Reynolds number based on the over-all length. Figures 3 and 4 show these curves for the representative series of models shown in Figs. 1 and 2. Solid lines denote experimental curves, whereas dotted lines denote extrapolation. The curve for the body with a pointed nose is considered not to be as accurate as the other curves. All attempts to produce a turbulent boundary layer on this pointed nose model caused a definite increase in the drag coefficient. It is believed that the increase in the drag coefficient was caused more by the drag of the turbulence producing material than by any effects that the material had on the boundary layer. The results for the other models are all considered to be satisfactory.

CALCULATED TERMINAL SINKING VELOCITY

The drag coefficient curves were extrapolated parallel to the Schoenherr skin friction curve. This technique assumes that the form drag of the bodies is constant within the range of the Reynolds numbers that are involved (10^6 to 10^8).

Terminal sinking velocities were calculated for all of the model configurations. Figure 5 shows the results of these calculations for a hypothetical projectile having the volume (0.3825 cu ft) and the density in air (169.5 lb per cu ft) of the 6-in. Projector Charge, Ex. 1 (BuOrd Sketch No. 239308). The curve for the projectile with the pointed nose is not considered to be accurate because of the previously mentioned experimental difficulties.

It is to be noted that over the range of variables shown in Fig. 5 there are no optimum length-to-diameter ratios. Consequently, for this configuration it is impossible to specify optimum design characteristics for a free sinking projectile within the limits of this experimental investigation. It should be noted, however, that for a given nose bluntness the highest terminal sinking velocity is attained by the more slender (greater length-to-diameter ratio) configuration. This feature is more pronounced for the blunt nosed shapes. A 15 percent increase in sinking velocity can be obtained by changing the length-to-diameter ratio from

7 to 14 for the configuration with a 0.75 nose bluntness. Ten percent of this increase is caused by changing the ratio from 7 to 10. The change from a length-to-diameter ratio of 10 to 14 produces only an additional 5 percent improvement in the sinking velocity. The fine nosed bodies show as little as 2 percent increase over the same range. The previously reported terminal sinking velocity of the 6-in. Projector Charge Ex. 1 is plotted for comparison in Fig. 5. It has a nose bluntness of 0.50 and a length-to-diameter ratio of 7.3.

The result of a test on a finless projectile configuration of 0.625 nose bluntness ratio and a length-to-diameter ratio of 7 is plotted in Fig. 5. It is of interest to note that the removal of the fins results in a 5 percent increase in the terminal sinking velocity.

EFFECT OF VOLUME AND DENSITY ON TERMINAL SINKING VELOCITIES

Terminal sinking velocities of a projectile of 0.50 nose bluntness ratio were calculated for a series of volumes and densities.

Figure 6 shows the effect of length-to-diameter ratio on the terminal sinking velocity of a projectile of constant volume for various densities. The highest sinking velocity is attained by the more slender configurations. The increase in sinking velocity produced by changing the length-to-diameter ratio from 7 to 14 is 15 percent for a density of 100 lbs per cu ft, decreasing to 10 percent for a density of 250 lbs per cu ft.

Figure 7 shows the effect of the length-to-diameter ratio on the terminal sinking velocity of a projectile of constant density for various volumes. The more slender configuration (L/D of 14 as compared to 7) results in a 10 percent increase in terminal velocity for all volumes.

Figures 8 and 9 are plotted from the curves in Figs. 6 and 7, respectively. The effect of density and volume on the terminal velocity is shown for several length-to-diameter ratios.

Practical design considerations may require a projectile which has a configuration which is less slender than the ideal shape. It is of considerable interest to know what penalty occurs when designing away from an optimum configuration. The curves in Fig. 8, for example, indicate that a projectile with a length-to-diameter ratio of 10 or more suffers a velocity penalty of less than 3 percent when compared with one with a ratio of 14. However, a drag penalty of 11 percent occurs if the ratio is as low as 6.445 compared with one of 14. For blunt nosed bodies it appears that a moderately slender projectile configuration (length-to-diameter ratio of 10) can be nearly as effective as more slender configurations.

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3. Kermeen, R. W., "Pitching Moment Balance for the High Speed Water Tunnel", California Institute of Technology, Hydrodynamics Laboratory, Memo. Report EM-12.4, April 15, 1952.

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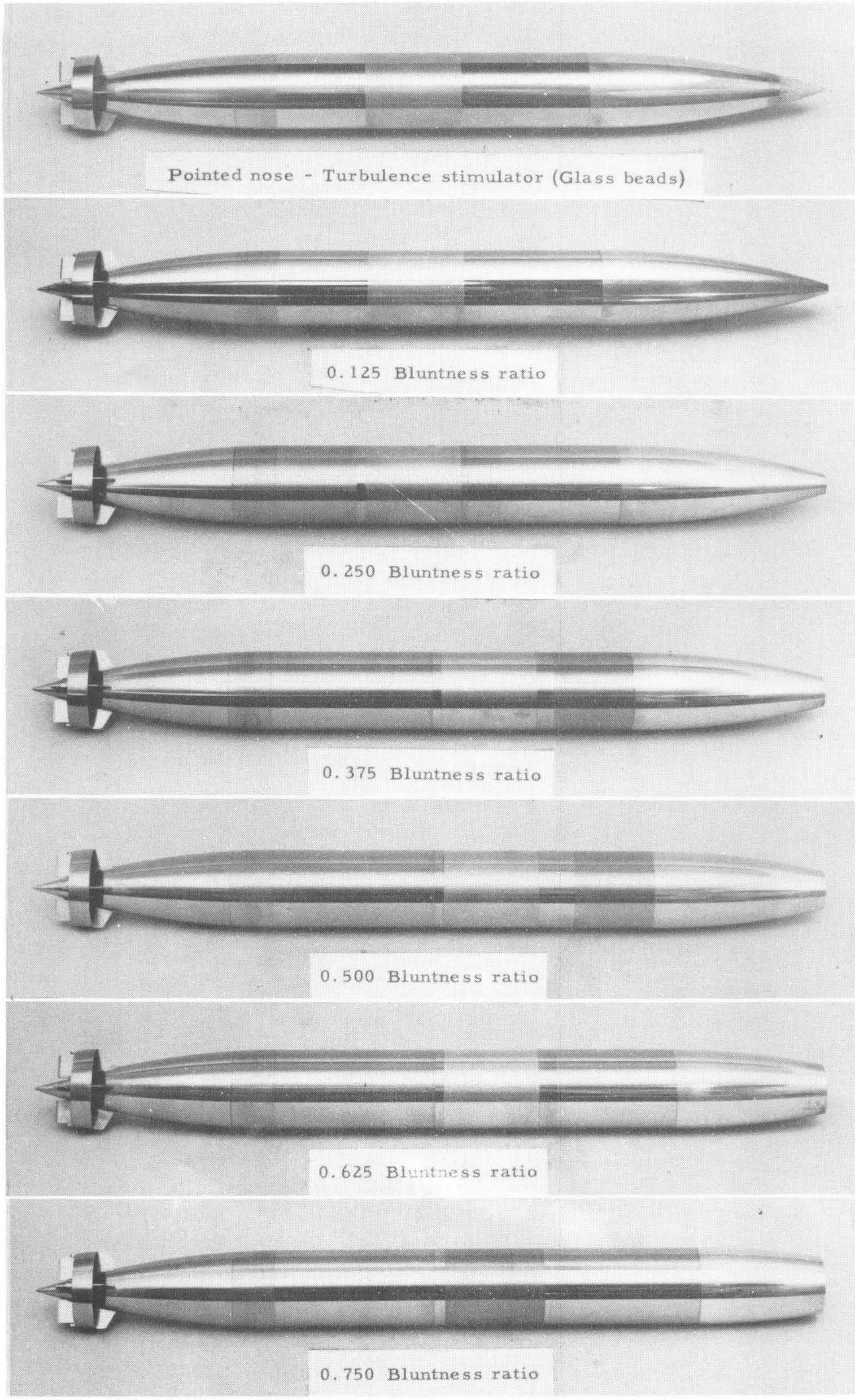

Fig. 1 - A series of representative models with various nose bluntness ratios for a length-to-diameter ratio of 10.

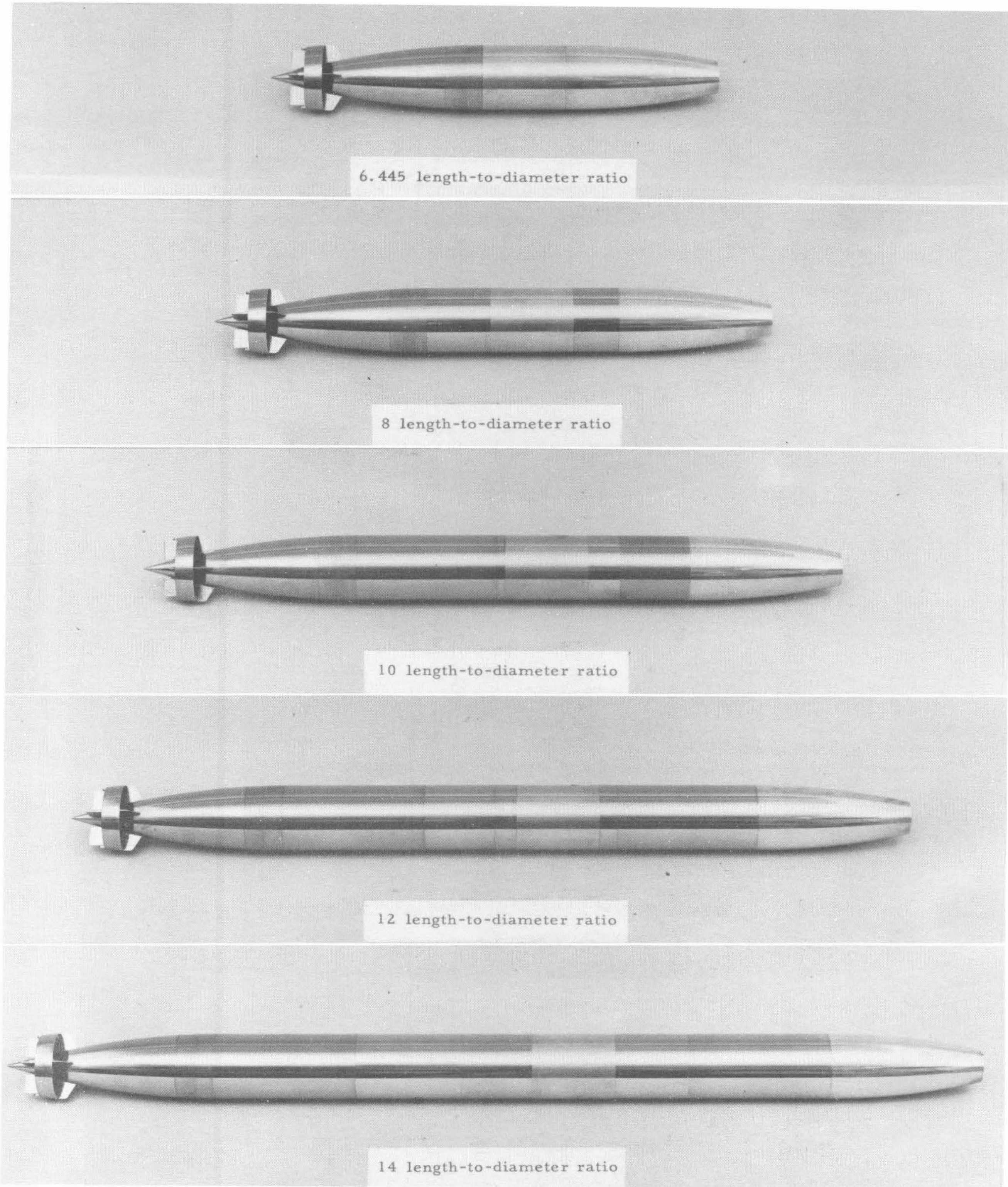

Fig. 2 - A series of representative models with various length-to-diameter ratios for a nose bluntness ratio of 0.50.

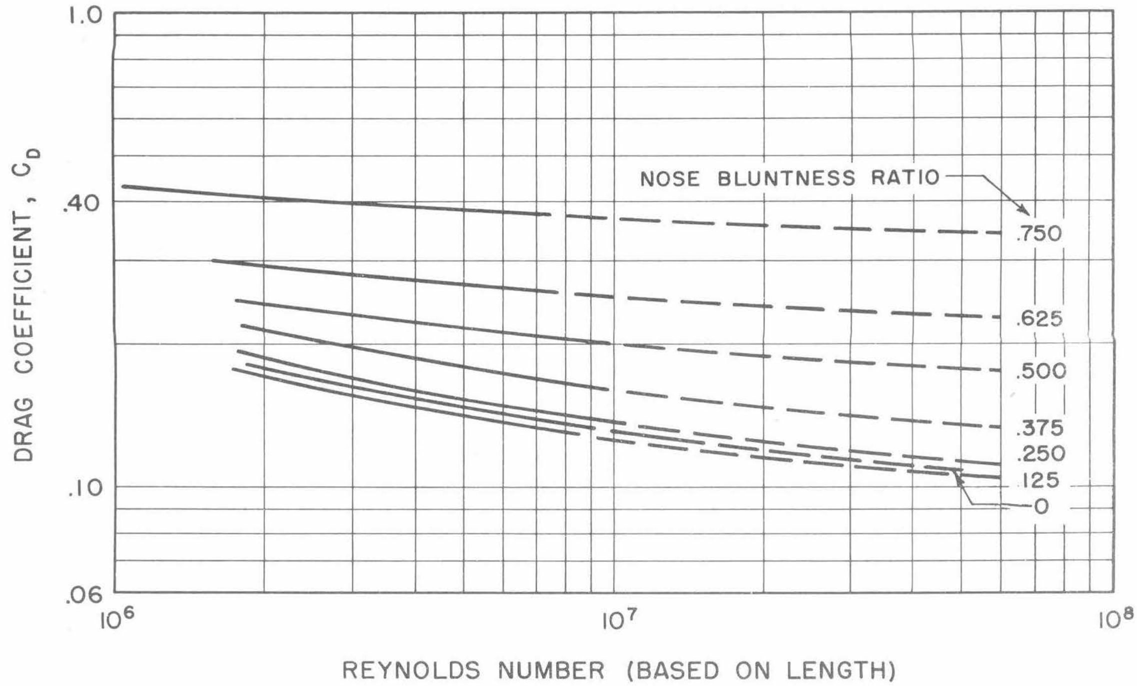

Fig. 3 - Drag coefficients based on cross section area for a series of models of various nose bluntness ratios for a length-to-diameter ratio of 10.

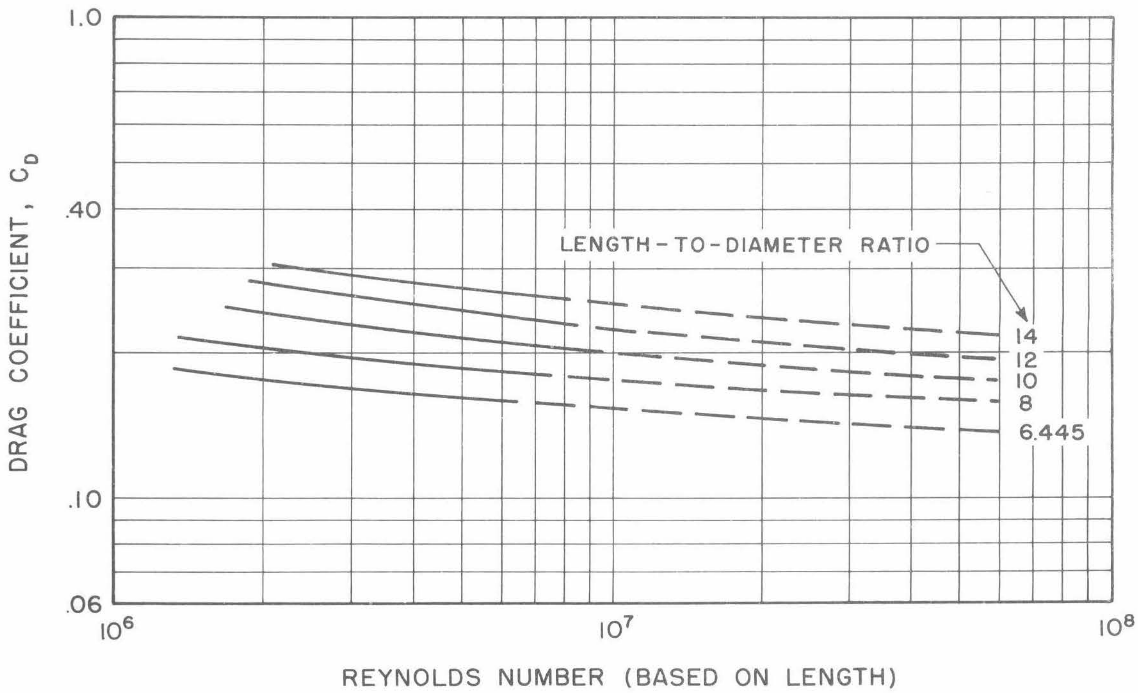

Fig. 4 - Drag coefficients based on cross section area for a series of models of various length-to-diameter ratios for a nose bluntness ratio of 0.50.

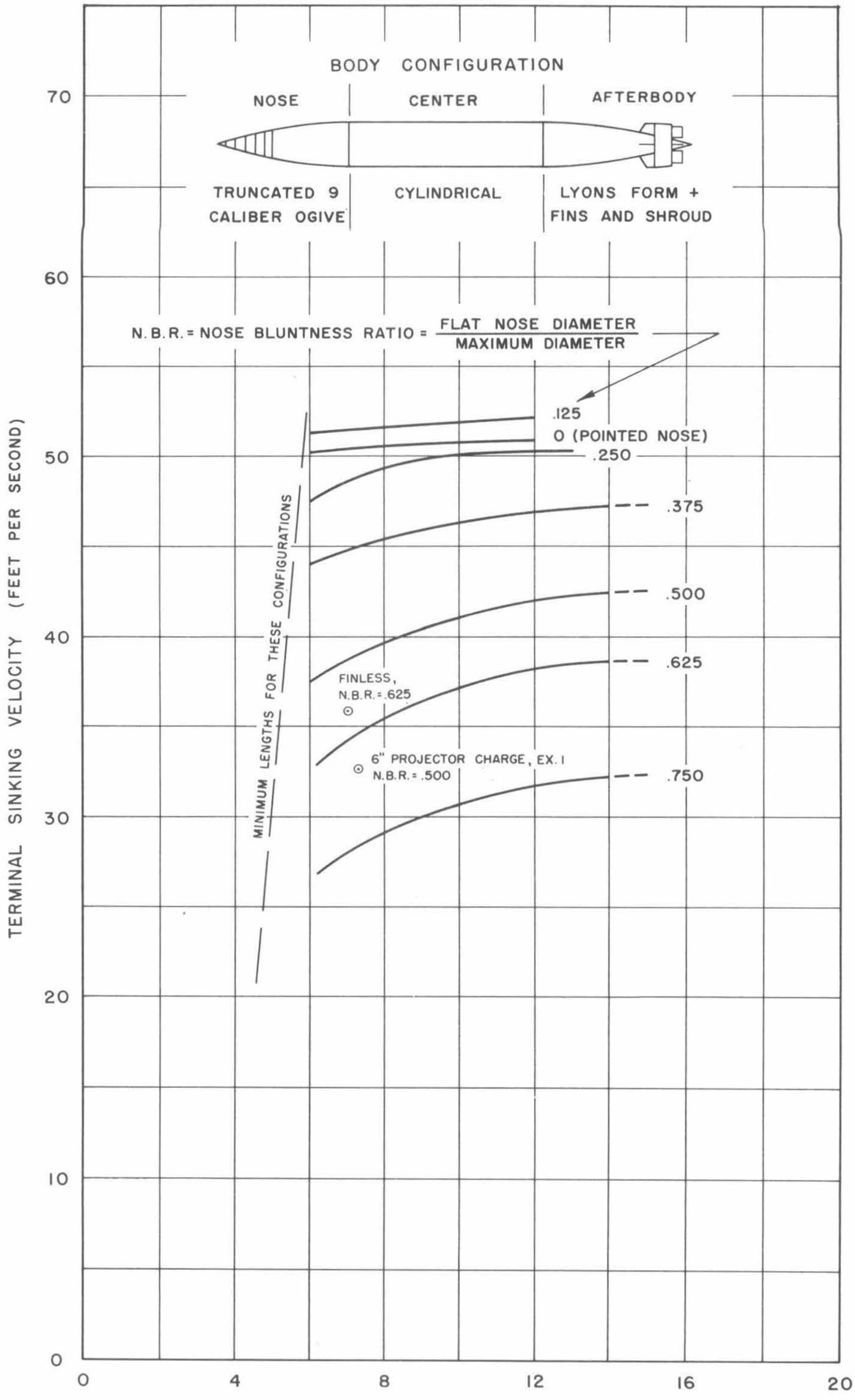

Fig. 5 - The effect of length-to-diameter ratio on terminal sinking velocity for a series of projectiles of various nose bluntness ratios. (Same volume and density as 6-in. Projector Charge Ex. 1. Vol. = 0.3825 cu ft; Density = 169.5 lbs/ft^3.)

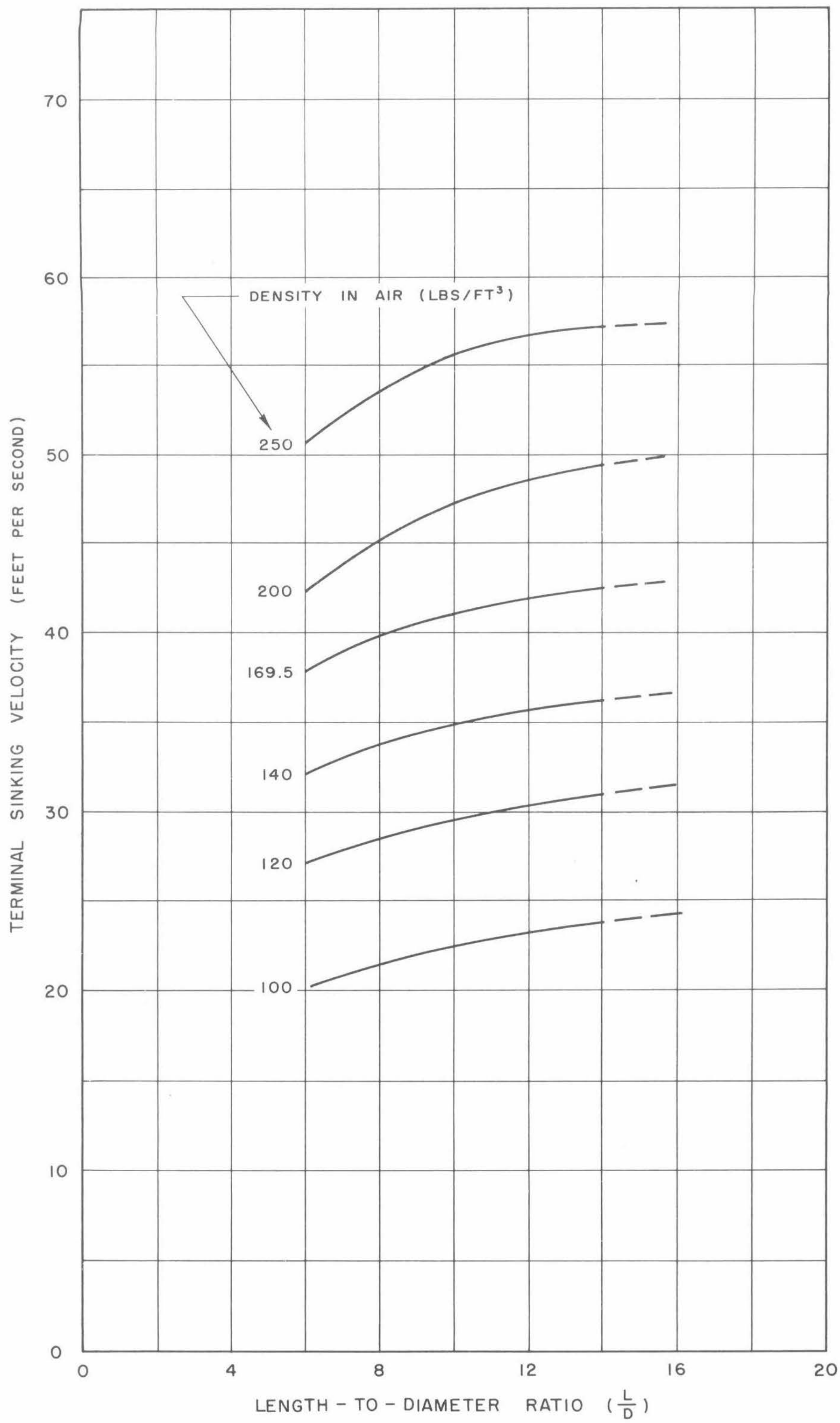

Fig. 6 - The effect of length-to-diameter ratio on terminal sinking velocity of a projectile of 0.5 nose bluntness ratio for various densities. (Same volume as 6-in. Projector Charge Ex. 1. Vol. = 0.3825 cu ft.)

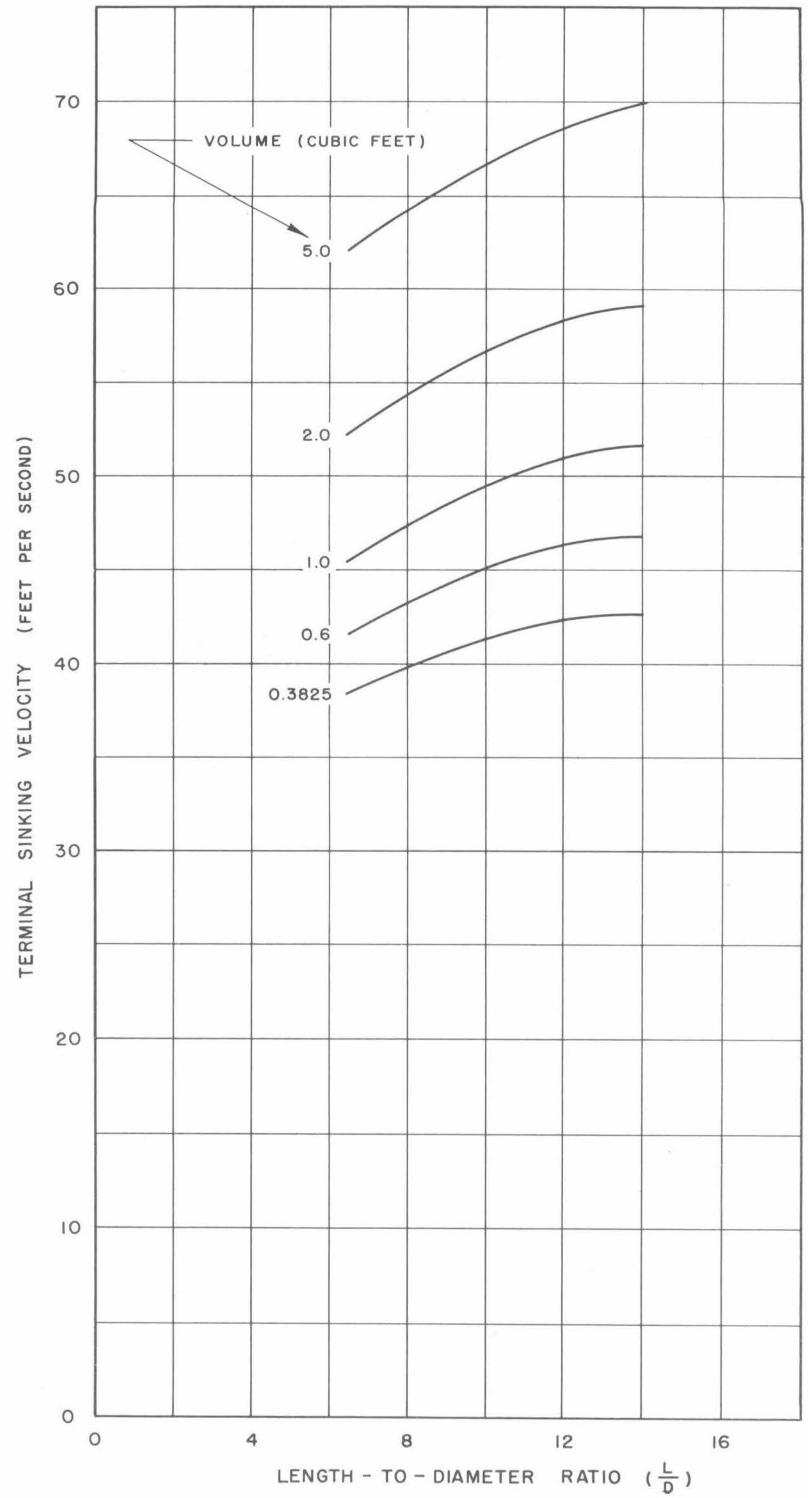

Fig. 7 - The effect of length-to-diameter ratio on terminal sinking velocity of a projectile of 0.5 nose bluntness ratio for various volumes. (Same density in air as 6-in. Projector Charge Ex. 1. Density = 169.5 lbs/ft^3.)

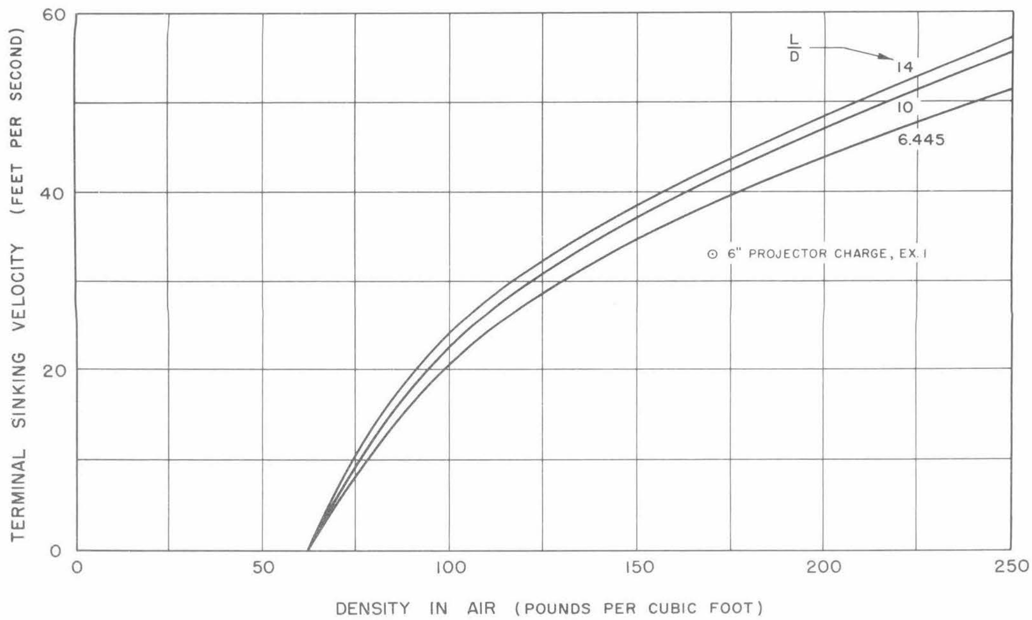

Fig. 8 - The effect of density on the terminal sinking velocity of a projectile of 0.5 nose bluntness ratio for three length-to-diameter ratios. (Same volume as 6-in. Projector Charge Ex. 1. Vol. = 0.3825 cu ft.)

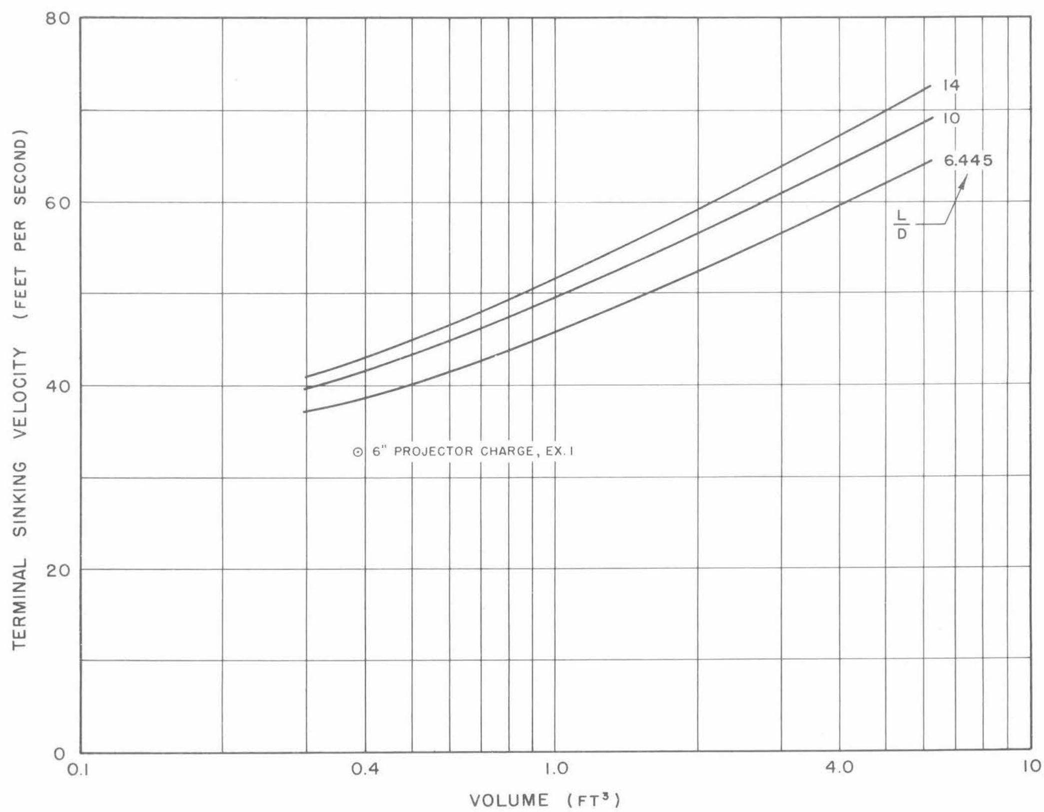

Fig. 9 - The effect of volume on the terminal sinking velocity of a projectile of 0.5 nose bluntness ratio for three length-to-diameter ratios. (Same density in air as 6-in. Projector Charge Ex. 1. Density = 169.5 lbs/ft^3.)

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